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RAFTS: A T-38 REPLACEMENT FOR THE 21st CENTURY

MAJOR RAYMOND C. CHAPMAN JR., 85-0435

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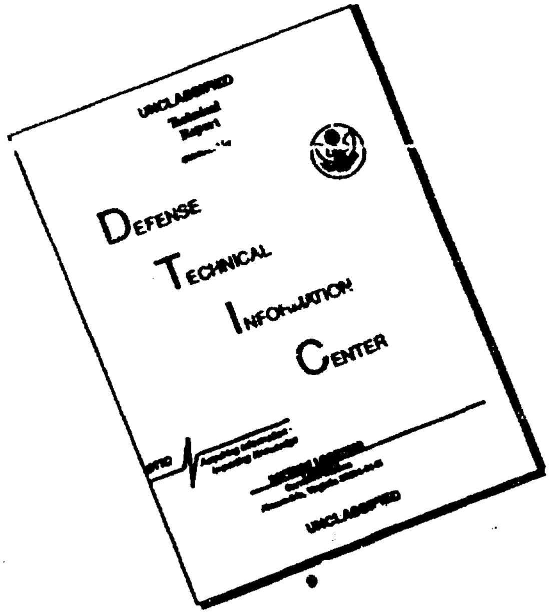

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The Reconnaissance Attack Fighter Training System (RAFTS) is designed to bridge the performance and systems gap between the T-46A and the Advanced Tactical Fighter (ATF). This training system will replace the T-38 now used in undergraduate pilot training. The study addresses the probable training environment, technology, training requirements, syllabi, and embedded training systems in the late 1990s. The study concludes with a conceptual design of the T-38 aircraft replacement for the 21st century.

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PREFACE

System acquisition of new aircraft for the U. S. Air Force inventory is a lengthy process. In recent years, the time from conceptual aircraft design to rubber on the ramp has been steadily increasing. The Advanced Tactical Fighter (ATF) has been in the acquisition process to date for fourteen years and is still not flying. This long acquisition process has prompted Air Training Command (ATC) to look at the twenty-four year old T-38 used in Undergraduate Pilot Training and to start looking toward the future for its replacement.

The purpose of this paper is to establish the conceptual framework which will be used to define a replacement for the T-38 aircraft used in Air Training Command. The author looks at the flying training environment in the 1990s and then focuses on what the Air Force's Advanced Tactical Fighter will look like by the year 2000. Based on this look into the future, the author proposes training requirements and a syllabus which will prepare student pilots for the advanced fighters. Future technological advances in flight performance, avionics systems, and embedded training systems will be combined to produce a conceptual view of the replacement T-38 which will train pilots into the 21st century.

This study will be used in conjunction with other research by ATC to prepare a draft Statement of Need (SON) to replace the T-38.

Many thanks to Major Bill Vinal, HQ ATC/XPS, for his patience and assistance in helping prepare this study.

ABOUT THE AUTHOR

Major Chapman spent ten years in Air Training Command prior to attending Air Command and Staff College. He served as a T-38 instructor pilot, check pilot, and member of the standardization and evaluation team logging over 1,700 flying hours in the T-38. Most recently Major Chapman was assigned to Headquarters Air Training Command, Operational Plans Directorate, Developmental Programs Division as an Air Operations Staff Officer for four years. He worked on the acquisition of the new T-46A aircraft and helped formulate the Specialized Undergraduate Pilot Training program. In addition, he was a member of the team which drafted the ATC operations input to the Air Force Project 2000, and the operations point of contact for matters regarding the new U. S. Navy training aircraft the T-45. He also formulated the T-46 and SUPT implementation plans which will be used by ATC through the early 1990s.

Prior to entering the Air Force Major Chapman served with the U. S. Army as a helicopter pilot for four years. He flew the AH-1G Huey Cobra in Vietnam and spent two years as a helicopter instructor pilot. He has logged 1,900 flying hours in helicopters, which include 1,000 hours of combat time in Vietnam.

He is a graduate of the University of Texas at Arlington with a Bachelor of Science in Chemistry and earned a Masters in Business Administration from the University of Texas at San Antonio while assigned at Randolph AFB.

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EXECUTIVE SUMMARY

REPORT NUMBER 85-0435

AUTHOR(S) MAJOR RAYMOND C. CHAPMAN JR., USAF

TITLE RAFTS: A T-38 REPLACEMENT FOR THE 21st CENTURY

I. Purpose: To establish the conceptual groundwork for a Reconnaissance Attack Fighter Training System (RAFTS) as a replacement for the aging T-38. The new aircraft would be designed to fill the Fighter Attack Reconniassance (FAR) role in Specialized Undergraduate Pilot Training (SUPT) during the late 1990s and into the 21st century.

II. Problem: The T-38 now used in Undergraduate Pilot Training (UPT) is approaching twenty-four years old and by 1996 will be thirty-five years old. Because acquisition of new aircraft is a lengthy process, the conceptual design for a T-38 replacement must be started now in order to bridge the performance and systems gap between the new T-46A primary trainer and the Advanced Tactical Fighter (ATF) in the 1990s.

III. Data: The training environment of the 1990s will be based on the new T-46A and SUPT. The advanced systems and performance of the T-46A coupled with the "dual-track" training program will enable ATC to specialize its training in the FAR track after graduation from primary (T-46A). The technology available and the enemy threats envisioned for the 1990s will produce advanced fighters very different from our current F-15/F-16 fleet. The training requirements needed to fly these future sophisticated aircraft will change dramatically as high mach cruise, Short Takeoff and Landing (STOL), and fully integrated digital cockpits become the standard. A look at the proposed performance capabilities of the T-46A and the ATF in conjunction with the current and future technology indicates the need for a RAFTS to transition students into the ATF. To take full advantage of the specialized training track, a combination of the UPT, SUPT, and Lead-In Training (LIT) syllabi will be incorporated into one RAFTS syllabus. This will result in one integrated training

program taking maximum advantage of the training transfer. In conjunction with the flying syllabus, advances in embedded training systems such as computer assisted instruction and instrument flight simulators with advanced optical displays will complement the ground training portion of the syllabus. A combination of the training environment, training requirements, T-46A and ATF performance capabilities, embedded systems, and the syllabus provides the basis for the conceptual design of the T-38 replacement.

IV. Conclusion: The RAFTS conceptual design is not only feasible, but the next logical step in the Air Force's continual need for upgrading our training aircraft. Just as other aircraft in the past have retired, so will the T-38. The conceptual design of the T-38 replacement will include fully integrated digital cockpits with "glass gauges" and wide angle Heads-Up Displays (HUDs). The aircraft controls will be fly-by-wire with electronic co-pilots to assist in systems management. A high lift wing will enable the aircraft to be STOL capable and highly maneuverable in the sub-sonic region, and also capable of supersonic dash. The rear cockpit will provide the instructor with excellent visibility both in the landing phase and in air-to-air work. Use of composite materials will decrease the weight of the aircraft and provide a thrust-to-weight ratio near 1:1. This conceptual design of the T-38 replacement and the RAFTS is a first step toward addressing the Air Force's training need into the 21st century.

V. Recommendations: Air Training Command and Aerospace Systems Division should continue to study the RAFTS concept. Preparation of a Statement of Need (SON) and continued research should lay the groundwork for future funding and ultimately contractor design involvement. This study is a first attempt to identify the major factors needed to initiate a T-38 replacement acquisition effort. Hopefully, it will promote more interest, study, and analysis, as we look toward the 21st century and a new Reconniassance Attack Fighter Training System.

Chapter One

BACKGROUND: THE T-38 LEGACY

The United States Air Force is currently using the T-38 aircraft as its training aircraft in the basic phase of Undergraduate Pilot Training (UPT) (22:1). Since 1961, the Air Force has produced pilots who graduated from UPT after completing the T-38 phase of training. The T-38, called the "Talon," the "white rocket," and the "sports car of the Air Force," has been one of the most highly successful aircraft the Air Force has ever purchased, serving numerous roles in training and operational support. It has attained the best safety record of any supersonic aircraft in existence with a current loss rate of only 1.6 aircraft per 100,000 flying hours, and it has continued to challenge fledgling pilots for twenty-three years in their quest for pilot wings. The aircraft's basic systems and its utility are evident in the use of the T-38 as a National Aeronautics and Space Administration chase and training aircraft, photo reconnaissance/chase aircraft at Edwards AFB, Lead-In Trainer (LIT) aircraft at Holoman AFB (26:1), and former aircraft of the US Air Force Thunderbird demonstration team. Since the aircraft first rolled off the assembly line in 1961 at the Palmdale plant of Northrop, 1,187 T-38s were built. In 1971, the last T-38 came off the production line. The aircraft is most simply described as a supersonic twin engine, tandem ejection seat model. For the sixties, the aircraft took advantage of almost all the technology of its time. The design was made with the classic "coke bottle" fuselage and actually held the world time to climb record prior to the McDonnell Douglas F-4. A basic training aircraft with this technology and a world record was unheard of before the T-38.

The T-38 performance characteristics were designed to prepare pilots for future fighter aircraft. Its high speed mach capability, high "G" capability, maneuverability, and final approach speed were all compatible with planned future fighter designs. In fact, the T-38 has now trained pilots from the F-100 era into the modern F-16. The T-38's remarkable training legacy has proven its value and capabilities over twenty-three years and has earned a place in the annals of pilot training history, but the T-38 cannot last forever. Major modifications, including rewinging the aircraft, have kept the fleet flying even though the total number of aircraft is dwindling each year by four or five aircraft through accident attrition. This dwindling number of aircraft, coupled with outyear programmed pilot production rates of 2,020 pilots a year (23:4), will eventually affect our ability to produce pilots. Current predictions estimate an insufficiency of T-38 aircraft will occur in the mid to late 1990s.

Certainly additional modifications to lengthen the service life of the T-38 will be accomplished to insure the aircraft's role into the early 1990s (13:6-7). However, no aircraft, not even the "white rocket," can sustain itself through the constant touch-and-go practice, rapid engine cycling, and high "G" maneuvering that the T-38

performs on almost every mission. The T-38 fleet flies approximately 300,000 hours a year and averages 200 launches per training day at a typical UPT wing (23:4). Couple that with the fact the majority of instrument missions are now conducted in the instrument flight simulator and you have an aircraft that does high "G" maneuvering and multiple touch-and-go landing practice on every sortie, and by 1990 it will be thirty years old!

For all its greatness, the T-38 will eventually fall short of accomplishing the primary mission which is training pilots for the fighter, attack, and reconnaissance world. As technological advances become more commonplace in our new fighters so will the need for a new training aircraft which can train future pilots. Cathode Ray Tube (CRT) instrument displays better known as "glass gauges", heads-up display, high mach capability, Short Takeoff and Landing (STOL), forward swept wings, and complex system cockpits are all here or on the drawing boards of major aircraft corporations. The McDonnell Douglas F-18 and Gruman X-29 are visible proof that these technological advances are here to stay (1:24). The T-38 design was careful to include the technology of its day, and we must now look at a trainer concept that will meet the needs of our Air Force through the 1990s and into the 21st century. We can ill afford to ignore the vital role that adequate training aircraft play in preparing our new pilots for front line fighters. The T-38 has done its job well, but we must plan for the future.

In order to develop a conceptual framework for the T-38 replacement there are several key areas to study. The methodology for this study includes a look at the future Air Training Command (ATC) pilot training environment, the Advanced Tactical Fighter (ATF), future training requirements, embedded training systems, and a proposed syllabus. This combination of future changes concludes in a conceptual design for the T-38 replacement.

Chapter Two

THE FUTURE ATC TRAINING ENVIRONMENT

Assuming the T-38 will have to be replaced, what will the training environment be in the 1990s? Concerning location, the training environment will probably be at the same six UPT wings Air Training Command is now using. Although adequate airspace is always a concern, the Air Force should be able to maintain adequate airspace to properly train new pilots. If the pilot training rate remains as is presently programmed and does not exceed 2,200 a year, the current locations will be sufficient. The real changes in the training environment will be the addition of the new T-46A (24:1) to replace the T-37 and the implementation of Specialized Undergraduate Pilot Training (SUPT) (27:3).

The T-46A will become operational for student training in January 1988 (24:4). It will take approximately five years to convert the UPT wings to the T-46A aircraft and its companion instrument flight simulator (IFS). The T-46A will take advantage of the latest technology as well as correct the training deficiencies of the current T-37 fleet. The T-37 has been with Air Training Command since 1958, and the fleet will be approaching thirty years old when the first T-46A is integrated into the training program. The T-46A will contain more avionics than the T-38, such as a Very High Frequency (VHF) radio and have an improved instrument panel as well as the capability to utilize the NAVSTAR Global Positioning System. The NAVSTAR is a navigation system which can pinpoint an aircraft's location anywhere on the earth within 3-5 meters. In addition, the fuel efficient fan engines and ACEs II ejection seats will improve both the performance and safety features of the T-46A. The side by side seating of the T-46A, like the T-37, will capture the proven advantages of direct instructor pilot (IP) contact with student pilots during the early phases of pre and post solo flight. The cabin pressure system in the T-46A, absent in the T-37, will allow training at higher altitudes, more efficient cross country training, familiarization with cabin pressure systems, and fewer physiological incidents. An additional improvement over the T-37 will be the inclusion of G-suit connections in the T-46A to counter the effects of high "G" manuvering. These changes in the primary aircraft are significant because students will already be familiar with many of the present system differences confronting a new student when he moves from the T-37 to the T-38. Training in the T-38 will not have to introduce, as in the past, TACAN navigation, cabin pressure systems, "G"- suit training, and instrument training with an Attitude Direction Indicator (ADI) and Horizontal Situation Indicator (HSI). In short, the most difficult task students will be confronted with is the flight performance difference and the tandem seating arrangement.

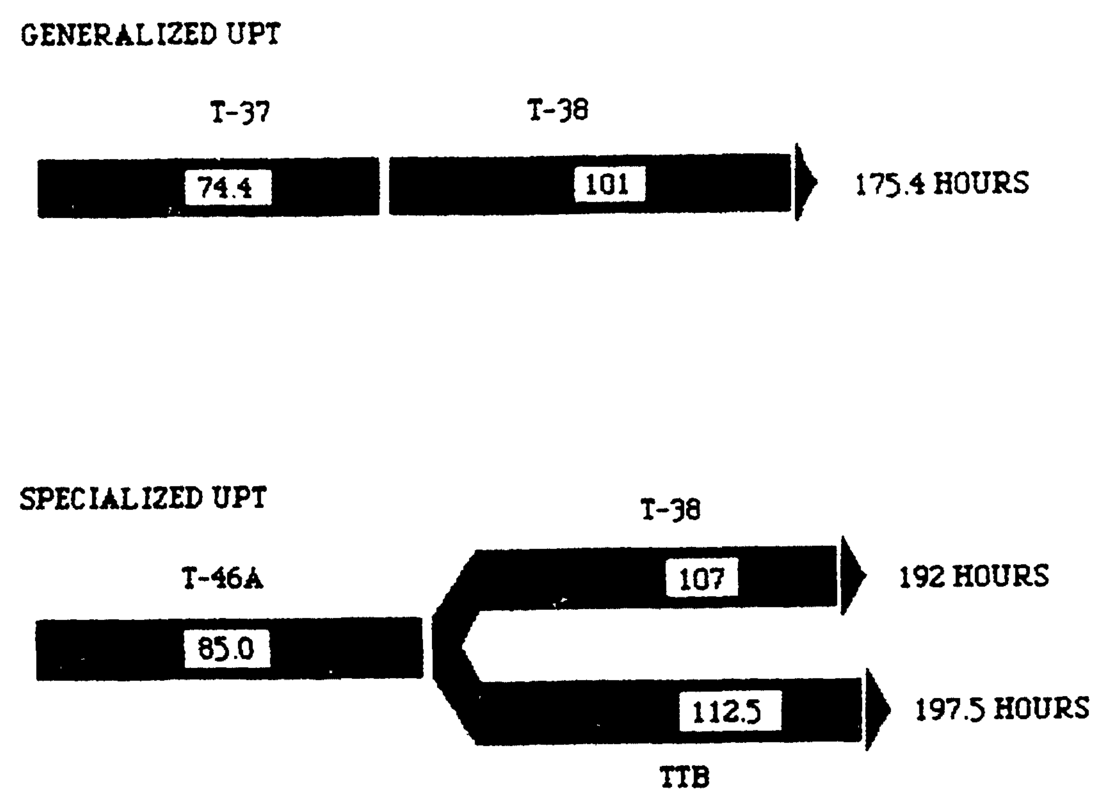
The performance difference, although significant, will not be as large a difference as previous students encountered in their transition from the T-37 to the T-38. In graphic terms, the T-46A capabilities will move students further down the continuum of learning systems and basic piloting skills prior to their first T-38

flight. In fact, with a system such as the NAVSTAR, the students will actually be taking a step backward in technology as they transition into the T-38, because it cannot accommodate the NAVSTAR (7:42-43).

The second major change in the pilot training environment will be the adoption of Specialized Undergraduate Pilot Training (SUPT). This specialized training concept is currently planned for initial operating capability in 1989 with funding starting in the 1987 Air Force Program Objective Memorandum (POM). The SUPT concept is not new to the Air Force and is the way pilots were trained until 1958 when the aging B-25 reached its service life and was retired (27:4). SUPT will enable the pilot training system to specialize students in "two tracks" after completion of the primary phase (Figure 1). Students who graduate from the primary phase will advance to either the Tanker, Transport, Bomber (TTB) track or to the Fighter, Attack, Reconnaissance (FAR) track. The specialized training in each basic track will be complemented by a longer primary phase of training in the T-46A. Students will receive ten additional hours in the T-46A including a formation check ride which is not required in today's UPT primary syllabus (27:8).

To take full advantage of the special FAR track, the proposed ATC syllabus will emphasize formation flying skills, low level pilotage, and advanced single ship maneuvers (28:1-4). Because the FAR track will train pilots selected for follow-on FAR assignments, the syllabus can be much more responsive to the needs of the gaining major commands. For example, if the new fighters require an increased emphasis on formation landing skills, the syllabus could be changed to augment this training. ATC is presently limited to minor changes within the syllabus because the program is designed around a generalized pilot whose follow-on assignment is unknown until six weeks before graduation. These two changes to the pilot training system, the T-46A and SUPT, will be the major changes in ATC's training environment by 1990.

The T-38 will experience increasing difficulty bridging the technology and performance gap between the T-46A and the future advanced tactical fighters. Although ATC is primarily responsible for training basic skills, a skill that is considered advanced today may be basic ten years from now. For example, years ago Instrument Landing System (ILS) approaches were considered advanced training requirements. Today the ILS approach is considered a primary pilot skill and is trained in the T-37 which has been modified to include the system. As our future weapon systems become more technologically advanced, pilots will require an ever widening array of systems training in conjunction with a thorough program of basic piloting skills to prepare them for the future fighters of the 1990s and beyond.



UPT & SUPT COMPARISON

Figure 1

Chapter Three

THE ADVANCED TACTICAL FIGHTER

The advanced tactical fighter of the future will be capable of supersonic cruise, high maneuverability, extended range, integration of systems, and a minimal radar signature Durability of the systems and its engine will also be key elements of the ATF. The engines will have to provide increased thrust for supersonic cruise flight as well as better fuel efficiency than our current aircraft. The supersonic cruise capability is planned for military power, which will give pilots afterburner when needed for a fight or disengagement when outnumbered (12:74-78). The ATF will also be capable of short field takeoff and landing (STOL), but not vertical short field takeoff and landing (VSTOL). This requirement is based on a proposed operating runway of 2,000 feet which would probably be the available runway left after enemy attack (10:47).

The ATF will also use Very High Speed Integrated Circuit (VHSIC) chips to facilitate the integration of the aircraft's systems. These chips will provide increased reliability, reduced weight, and reduced cost compared to other available chips (11:44). In the cockpit, advanced Heads-Up Display (HUD) (21:51-53) as well as improved communications using the enhanced Joint Tactical Information Distribution System (JTIDS) will allow for jam resistant, secure communications (4:58). In addition, the ATF will probably be able to execute decoupled manuevers. These are maneuvers in which the direction of the aircraft changes without changing its flight attitude. Simply stated, an aircraft could climb, descend, or turn without pointing the nose of the aircraft in that direction (8:38). The radar signature of these aircraft as seen by enemy radar will probably be a tenth of what the current fighters have. It will also fly low around terrain rather than over it in order to avoid the enemy radar This "stealth" capability, in concert with the supersonic speeds, will make hit and run attacks against ground and airborne targets a highly effective tactic (8:44).

An ever increasing problem for pilots is situational awareness. This is defined as the ability to simultaneously fly the aircraft, avoid enemy missles and fighters, talk on the radios, know where wingmen are, and acquire targets. As systems have become more technical, the operator's task to handle the offensive and defensive systems and to fly has become more and more complicated, but the ATF will probably have more automated systems to reduce the pilot's work load (18:24). Smart systems will keep the pilot informed of the enemy's position and even fly the aircraft while he becomes a decision maker based on the data presented to him. These "electronic copilots" will handle flight, engines, weapons, counter measures, communications, and navigation controls These auto pilots will be able to deliver bombs or missles during a high speed turn or barrel roll Such maneuvers would be impossible for a man to do because of the speed of the aircraft while acquiring a target (8:44-46)

To decrease weight and thus increase the range and thrust-to-weight ratio, light weight carbon-carbon and metal matrix composites will be used on the ATF (1:27). These lightweight composites, integrated throughout the aircraft structure, will allow for shorter takeoff and landing distances. The ATF will handle the difficult chore of controlling the aircraft, which requires "40 commands per second" to the flight controls, by using full digital "fly-by-wire" technology. Onboard computers, not a pilot, will handle this superhuman chore (20:20-25).

It is probable the ATF will have some type of two dimensional thrust vectoring and thrust reversing engine nozzles. The thrust vectoring improves lift and reduces drag to improve cruise fuel efficiency. The reverse thrust is used to reduce landing distances especially on a battle damaged or wet runway. The engine will most likely be of the turbojet design in order to meet the thrust requirements of supersonic cruise flight. This engine design is currently under study by U. S. engine manufacturers under the title of the Joint Advanced Fighter Engine (JAFE) program. The Air Force is trying to accelerate the engine program so that it will meet the aircraft design schedule (16:60-62).

In addition to the ATF, the Air Force is also working on a Transatmospheric Vehicle (TAV). The TAV will probably use many of the technologies developed from the research of the ATF. The TAV will be used for missions in lower space and the upper atmosphere. It could launch from a military airfield, go into an orbit, and re-enter to deliver cargo or weapons on tactical targets. Flight times for the TAV are estimated at 12 minutes from New York to Los Angles and 30 minutes from New York to Sydney, Australia. The TAV would be capable of speeds up to 30 mach; and, in contrast to the space shuttle, it would have air breathing jet engines as well as rocket motors. This manned, highy manueverable spacecraft/aircraft would provide offensive and defensive capabilities in the twenty first century (2:88-91)

A great deal of research emphasis is being placed on a supersonic capable Advanced Short Takeoff and Vertical Landing (ASTOVL) aircraft. This type of aircraft can enhance the launch and recovery of tactical aircraft to battle damaged, shortened runways. The capabilities of a supersonic ASTOVL aircraft could also be used by Naval and Marine air forces. Such a design could result in an aircraft common to all three services saving considerable research and development funds. The increasing vulnerability of fixed land bases and sea bases (carriers) has revived the ASTOVL concept. Many observers believe that by the year 2000, runway denial technology will make any aircraft without short takeoff and vertical landing capabilities inoperable in the European theater (4:56-57). Although the cost of such an aircraft was once considered prohibitive, new technology in the current Vertical Takeoff and Short Landing (VTOSL) aircraft (AV-8B Harrier) has improved designs on the airframe and engines In addition, the high thrust required on today's fighters makes the price paid for high thrust VTOSL engines more palatable. Contractors working on the new ASTOVL concepts expect to have a flying demonstrator by the end of this decade.

Finally, the cockpits of future fighters will take full advantage of current and future technologies (9:80-83). Already "glass gauges", a Cathode Ray Tube (CRT), are commonplace in our front-line fighters such as the F/A-18 and F-16C. These miniature TV screens can project data such as ground mapping and radar, as well as flight control and performance information. The glass gauges are reliable and are integrated into the computer fire control systems (Figure 2).

Another modern system now often found in aircraft is the heads-up display (HUD). The HUD will soon be certified by the FAA for use in transport type aircraft to accomplish instrument approaches down to catagory 3A minimums of 50 feet ceiling and 700 feet runway visibility (15:145). Most HUDs consist of optical glass combined with a gelatin material to reflect symbology generated by a CRT. When mounted in the pilot's forward field of view, the HUD provides the pilot with a combination of outside references as well as digital cockpit instrument data. Of course, HUDs have been used by fighter/attack aircraft for many years, but even these aircraft will be receiving new and improved models (17:37). Wide angle HUDs to improve the pilot's total vision area as well as helmet mounted HUDs will be commonplace by 1995 (1:73). All of this technology which will be built into the ATF will change the training requirements for both the Tactical Air Force (TAF) and ATC

F/A-18 HORNET COCKPIT

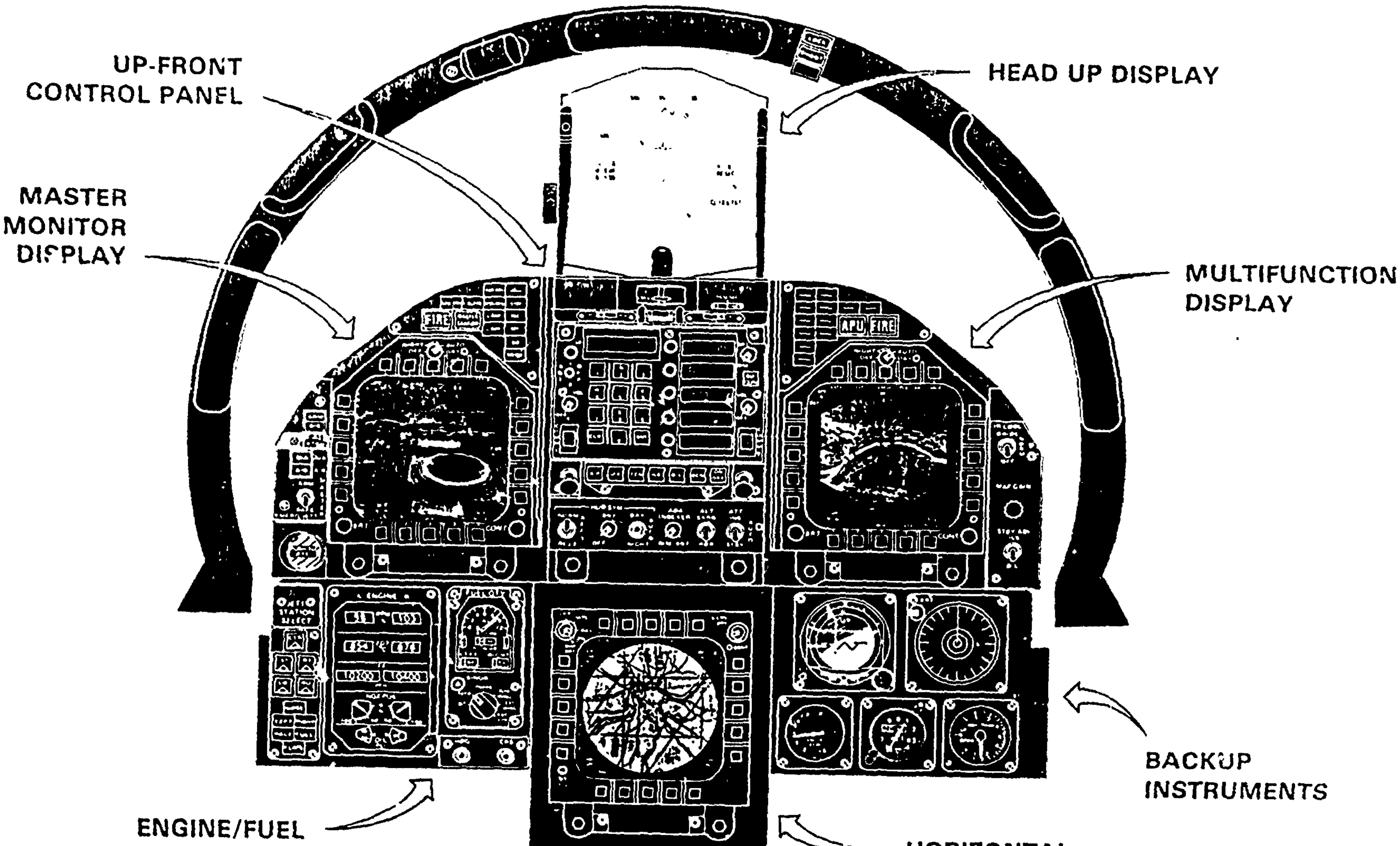


Figure 2

Chapter Four

TRAINING REQUIREMENTS OF THE 1990s AND BEYOND

Pilot training requirements must bridge the piloting skills gap between the T-46A and the ATF as well as prepare students with the basic systems knowledge needed to transition to the ATF after graduation from pilot training. Since the ATF is only on the design boards of contractors and the T-46A has yet to make its first flight, the training requirements can only be postulated on proposed future data as well as the historical methods of establishing training requirements ATC's responsibility to the Tactical Air Force (TAF) is to provide pilots who meet course training standards and are capable of moving into a fighter type aircraft. Training requirements have changed very little since the introduction of the T-38 into the Air Force inventory in 1961. The reason for this is the T-38 is limited to its current configuration. Very little can be done to improve its performance capabilities or significantly modify the aircraft systems. Funds to modify training aircraft are normally delegated to maintain safety of flight, such as re-winging the entire T-38 fleet, and not to provide enhanced systems modifications. Currently the training requirements of the TAF are being met by ATC Periodic course training standards conferences are conducted to insure ATC is providing the TAF with pilots that meet their needs within the current T-38 limitations. In the future though, ATC will be unable to train pilots with the skills necessary for the ATF as long as the T-38 is used as the final undergraduate training aircraft.

Opponents to an improved ATC training aircraft believe that the TAF should provide the specialized training needed for transition to tactical fighter/attack aircraft as they currently do in the Lead-In Training (LIT) program. They contend that ATC's job is to provide a pilot with the basic skills, and the TAF will then mold the pilot and provide the advanced training necessary for front-line fighter operation. However, as technology advances, the definition of basic skills must also change. In the 1950s, UPT graduates started their primary training in a single engine prop T-28 or T-34A aircraft. In 1990, primary students will start the undergraduate course flying the twin fan-jet T-46A, equipped with full instrumentation and the latest ejection seats common to our most modern fighters. Now students are taught advanced instruments such as ILS approaches in the primary phase of training, but in the fifties, the training aircraft didn't even have an ILS. In short, as advanced technology improves our fighter force, the training requirements in undergradute pilot training will also have to move forward with technology A new SUPT graduate, scheduled for transition to an ATF, will have considerable difficulty attempting a short field landing after practicing all approaches and landings at 155 knots indicated air speed (KIAS) in the T-38 Short field landings require different piloting skills which cannot be duplicated in a T-38 The vital transfer of training between the basic aircraft and the advanced aircraft would be missing and would result in a less than optimum, inefficient training program.

ATC will continue to teach patterns and landings, instruments and navigation, aerobatics, and formation flying, but new technologies will expand ATCs basic training requirements to prepare for transition to the ATF. To provide the TAF with graduates ready for the mid 1990s, ATC will need a training system which blends the advances of the T-46A and future training requirements into a Reconnaissance Attack Fighter Training System (RAFTS).

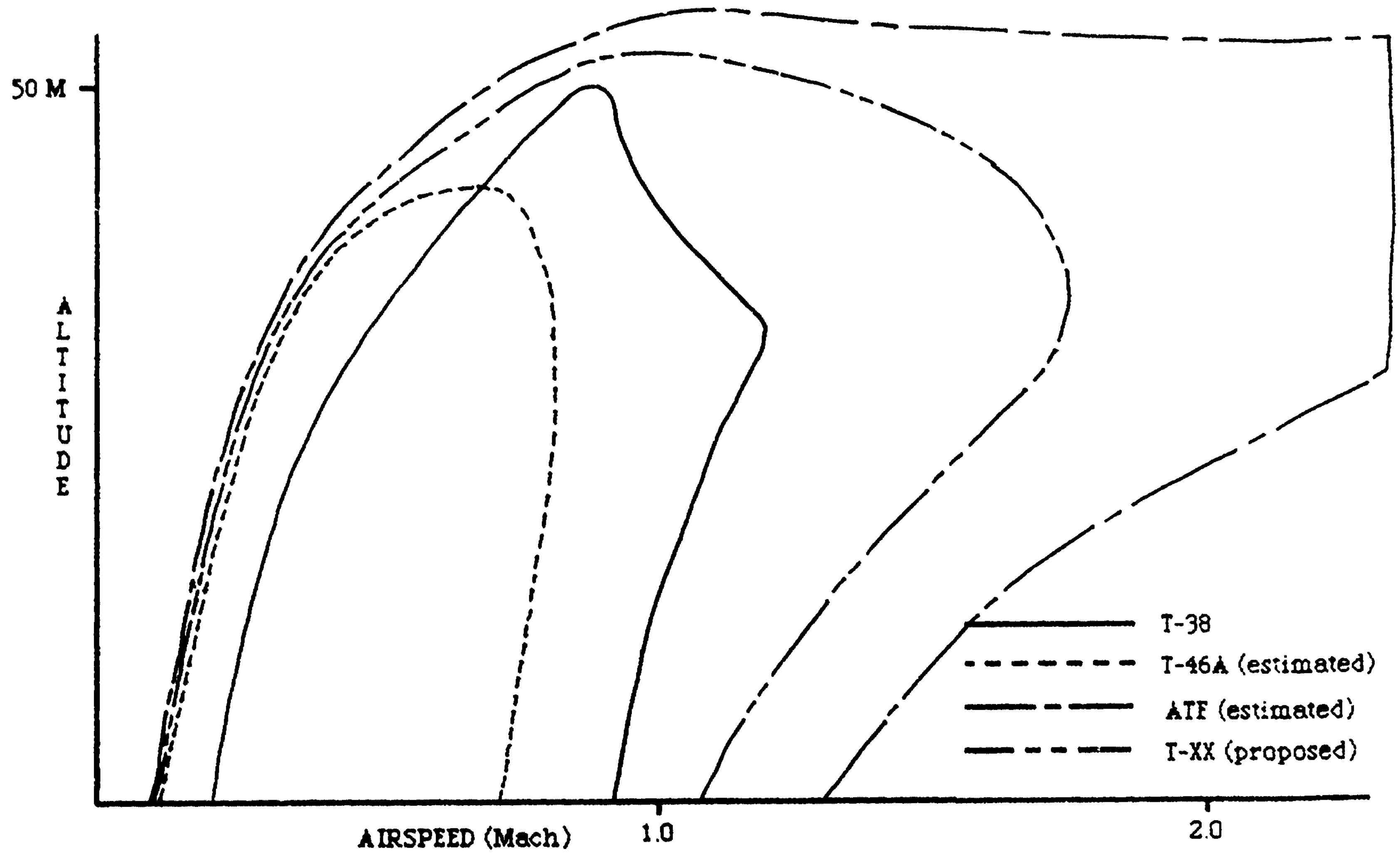
Chapter Five

RAFTS. THE T-38 REPLACEMENT

Training requirements drive aircraft design. Performance and systems which meet training requirements are the two key concepts which should be considered in the design of a new training aircraft. But for how long can an aircraft design effectively transition pilots to the ATF? Should it be expected to train pilots until 2010 or perhaps even until 2030? The T-38 is presently programmed to be in service with modifications until 2011. That would make it a forty-nine year old aircraft training pilots for a follow-on to the ATF. Clearly there is a limit to how long a training aircraft can provide the kinds of skills necessary for pilots entering the advanced tactical fighter world. The T-38 may last forty-nine years with structural modifications; however, a pilot who graduates from UPT in 2010 will have basically the same piloting skills as a pilot who graduated in 1961.

A new training aircraft could be built on the existing proven technology of the ATF of the 1990s, thus eliminating costly research and development funding. Currently the TAF uses a T-38B, a modified T-38, to prepare pilots before entering the A-10, F-111, F-4, F-15, and F-16 training programs. This modified T-38, complete with aiming sight, has a weapons delivery capability from the center pylon of the aircraft. The program is designed to fill the gap between the undergraduate and fighter pilot worlds. Students usually have little trouble learning the basics of flying an F-15 or F-16, but they are at a considerable disadvantage when it comes to systems operation of these complex modern day fighters. As mentioned earlier, the systems of the T-38 are the same today in 1985 as they were when the aircraft first trained student pilots in 1961. This trainer is being asked to work in tandem with the new fighter and its ever increasing array of systems as well as its higher thrust to weight ratio which means enhanced performance. The ATF will present an even greater challenge as it cruises along at supersonic speeds with advanced avionics and defensive and offensive systems that are presented to the pilot on CRTs with a wide angle HUD and a digital fly-by-wire flight control system. Although the aircraft will be largely controlled by a smart electronic co-pilot, the pilot will have to be prepared for the air to air engagement, change of ground target, and targets of opportunity. The pilot may also have to recover his aircraft on an airfield which has been reduced to 2,000 feet of available runway. No matter how automated the system becomes, a pilot will still be required to make decisions and fly the aircraft.

As mentioned earlier, the performance and systems of the aircraft are the keys to meeting training requirements. The T-38 replacement will have to be capable of supersonic manuevering flight and will require some STOL capability. Maneuvering aircraft at high speed can be as difficult as maneuvering at slow approach speeds The T-38, although capable of supersonic flight, can only achieve mach 1 in afterburner and usually in a slight decent at higher altitudes (Figure 3)



COMPARATIVE 1 "G" FLIGHT ENVELOPE

Figure 3

The T-38's basic approach speed is 155 KIAS minimum which is faster than any of the current front-line fighters. This high approach speed cannot train for STOL operations. The takeoff roll averages 3,000-4,000 feet depending on temperature, altitude, and wind; and its landing distance requires a minimum of 8,000 feet of runway for safe operation. Using current technology in wing design, the RAFTS should be able to achieve shorter takeoff rolls and shorter landing distances. The use of composite materials will add strength to the wing while decreasing weight. Composite wing technology will also allow the RAFTS to use forward swept technology and to use engines with less thrust because of the decreased weight and increased lift. The RAFTS should be supersonic capable, but not necessarily for sustained cruise operations.

A most important factor in the design of a new trainer is the maneuverability of the aircraft. It should be capable of sustained high "G" turns in the sub-sonic region with the turning capability of our present day fighters, the F-15 and F-16. The T-38 lacks this high "G" manueverability and makes the transition to the F-15 and F-16 aircraft a large step in performance. The T-38 can only maintain 4 1/2 - 5 "G"s in a military power turn at about 11,000 feet Mean Sea Level (MSL). Higher altitudes result in a constant loss of airspeed and/or altitude while maintaining a constant "G" of 4 1/2 - 5 (3:6). A wing with higher lift and less drag should be incorporated in the T-38 replacement to maintain these sustained "G" turns. This wing will also facilitate the requirement to make short field takeoffs and landings. Training students in a RAFTS aircraft that can make takeoffs and landings in 2,000 feet or less will not only prepare them for ATF or VSTOL aircraft, but also allow ATC to expand its use of civil and military airfields for training.

Another requirement of the RAFTS is an aircraft with two engines. ATC experience in the training environment has proven the advantages of two engines versus one. In the event of an engine failure, two engines give the new student time to react, call the supervisor of flying, and refer to the check list Although emergency procedures are often simplified in a single engine aircraft, students frequently panic at the onset of an emergency. A two engine aircraft gives a student additional time to analyze the situation which is an added safety factor in the training environment. Two engines are also important because of the added wear and tear sustained during the many training hours spent at the lower altitudes in the traffic pattern and during touch-and-go practice. An instructor pilot and student may spend an entire one hour and fifteen minute sortie doing touch-and-go landings while a tactical mission is terminated with a single full stop. With a two engine aircraft, engine malfunctions such as foreign object damage, loss of engine oil, or gearbox failures will not result in ejection, but in recovery via a single engine approach and the opportunity for that aircraft to fly another day.

Another requirement for the RAFTS is tandem seating in the aircraft. The tandem seating arrangement allows the instructor pilot to sit behind the student and monitor his performance as well as to demonstrate maneuvers and traffic patterns The critical requirement here is the visibility from the back seat. The instructor's cockpit should be elevated slightly to provide for clear vision in front of the aircraft The T-38 requires an almost blind landing by the instructor because as the aircraft approaches the runway side-to-side vision and lateral depth perception are the only keys to determining the initiation of the landing flare. The RAFTS should incorporate into its design an instructor's cockpit with good forward visibility throughout the landing phase.

Systems complexity along with the high performance of our current fighters have led to task saturation of our pilots. Although the RAFTS could not have the cockpit complexity of an ATF, the aircraft should be designed with enough modern systems to familiarize students with the basic systems inherent in advanced fighters This would initiate students in a training program in which CRTs, HUD, and digital fly-by-wire systems are standard in a basic cockpit. As the student pilot begins basic flight training in the T-38 replacement, systems management training will become an important element in the learning process. The student of the future will integrate cockpit systems into his thought process while learning basic flying skills The transfer of this systems integrated training to the ATF program will be a major advantage of RAFTS

Chapter Six

EMBEDDED TRAINING SYSTEMS

The embedded training systems for the RAFTS include simulators and all related ground training systems. The embedded systems should complement aircraft training and be integrated into the entire training system. The Instrument Flight Simulator (IFS) and Computer Assisted Instruction (CAI) are the two major systems which should be included in the RAFTS.

The instrument flight simulator currently used by ATC for the T-38 basic phase consists of a T-38 cockpit mounted on a motion platform with six degrees of freedom. The platform can simulate pitch, roll and yaw, and is coupled with a visual display (CRT) which corresponds to the flight parameters induced by the pilot For example, pushing on the control stick causes the platform to tilt forward slightly while the visual display shows a corresponding nose low shallow dive. Although several studies have been done to evaluate the benefits of a motion platform, the results have been inconclusive. ATC experience has revealed that students rarely realize if the motion system is turned off during an IFS mission because of their concentration on instrument flying. Instrument flying procedures are normally restricted to 30 degrees of bank and no more than 10 degrees of pitch. The flight parameters result in an imperceptible movement of the platform. The visual display on the CRT provides all the visual cues necessary to determine a change in bank or pitch. The "seat of the pants" feel that the platform is supposed to create is not only undetectable, but it is also unrealible, especially in actual weather conditions. The visual cues (instruments), not the "seat of the pants" feel from the platform or aircraft, keep a pilot from experiencing spatial disorientation. The IFS motion base for the RAFTS should be limited to the two degrees of movement necessary to provide minimum motion indications for approach to stall, turbulence, and landing touchdown

The visual system used for the RAFTS should be of the most modern technology available. Several manufacturers are already producing high quality, full color CRT displays for our newest production aircraft. The Federal Aviation Administration approves of the visual system for certifying commercial pilot's landing currency The low-level training program at Little Rock AFB for the C-130s can display the entire state of Arkansas on a CRT display suitable for actual terrain following. Certainly by the 1990s, these visual displays will be converted from CRT to laser optics with a three dimensional image display for the pilot The RAFTS should take full advantage of these visual displays in conjunction with a totally automated cockpit as part of the training syllabus.

Probably the most valuable training accomplished in an IFS is the instrument and emergency procedures training. Instrument procedures such as ILS appoaches, microwave approaches, and NAVSTAR can be practiced multiple times in the

simulator. The instructor can freeze the situation to discuss student errors or offer techniques before continuing. Basic and advanced instruments, HUDs, and inertial navigation can be blended into a mission which never leaves the ground. In concert with instrument system training is emergency training. Safety and good sense dictate that emergency procedures cannot be realistically practiced during actual aircraft sorties. The IFS can simulate engine, hydraulic, and electrical failures during a mission to test the student's judgement and flying abilities under stress. The realism provided by this kind of emergency procedures training is also a valuable confidence builder which can play a critical role in safely recovering the aircraft.

Simulators cannot be expected to take the place of actual flying time in the aircraft. The simulator mission is to complement the aircraft by introducing systems and procedures and perfecting instrument and navigation skills. The RAFTS should have a modern IFS as part of the total training system to capture the distinct training advantages of simulation, but not at the cost of aircraft sorties.

Computer assisted instruction (CAI) will also be an integral part of the RAFTS. The CAI allows students to sit in front of a CRT and to progress at their own learning pace while completing lesson plans in various phases of training. The advanced CAI used by the F/A-18 training program offers an example of what the RAFTS could do with CAI. The CAI is used not only for aircraft familiarization of systems, but also for communications, HUD, and radar intercepts training. The CAI when designed into the RAFTS would complete a total systems approach to training pilots (19:40).

CAI offers two distinct advantages when combined with an aircraft that possesses total digitally integrated systems. First, changes to the aircraft systems are software based. The CAI lessons are also software based. Thus, when changes are made to the aircraft software the same changes can be introduced to the CAI lessons. This results in the elimination of the tedious job of reprinting workbooks and other written lesson material to maintain their currency. Second, the computer generated display a student sees while using CAI would be the exact display generated in the cockpit. Students will not have to transpose digital information into analog representations or vice versa (19:46). (The T-38 uses analog information in the cockpit, more commonly called "round dials.")

The transfer of training using a CAI and a full digital cockpit would maximize the training benefit of the RAFTS, and the transition training course to the ATF. A total integration of ground, simulator, and aircraft systems between the RAFTS and the ATF would take full advantage of the specialized training concept, advanced technology, and transfer of training between training and operational aircraft.

Chapter Seven

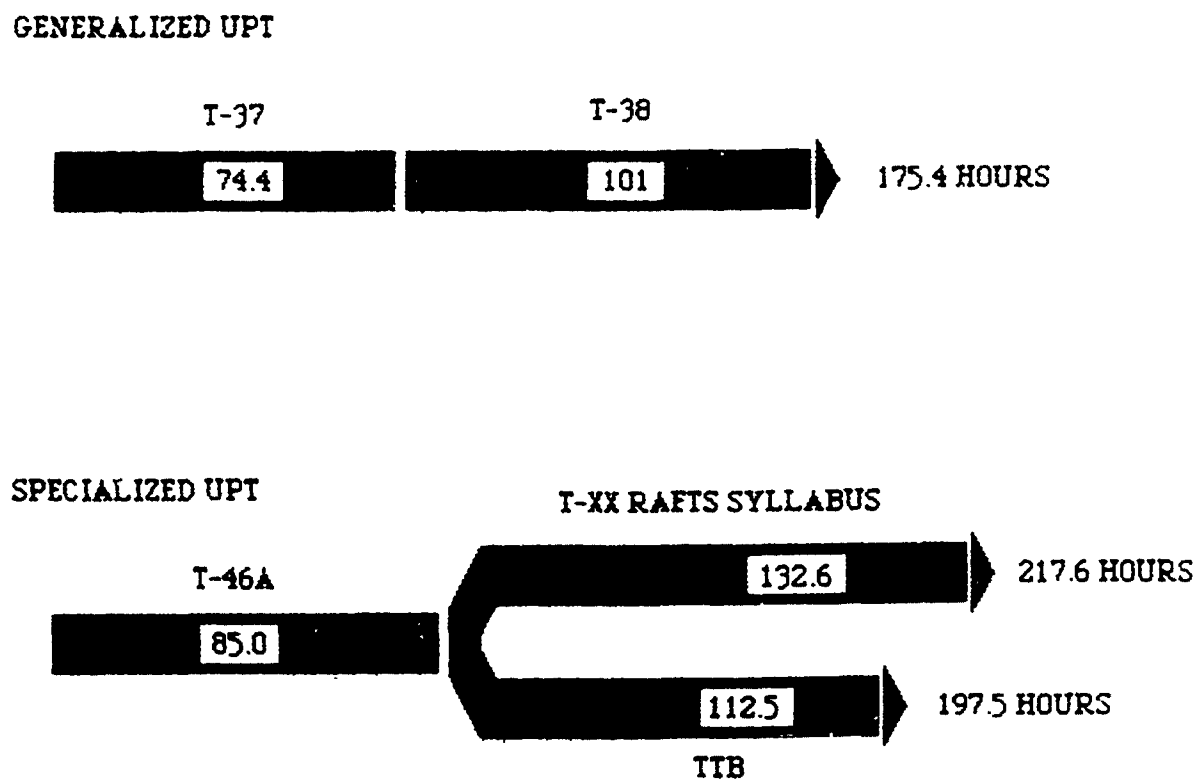
THE RAFTS SYLLABUS

At present, the UPT syllabus contains 101 flying hours in the T-38. The sorties are divided into contact, instrument, navigation, and formation blocks of instruction The SUPT syllabus that is planned for 1989 adds six additional hours for a new total of 107 flying hours. The added hours include two-ship low-level formation, a four-ship checkride, and advanced single-ship maneuvers. These additional sorties are designed to challenge students and to increase their breadth of flying experience within the current T-38 performance and systems limitations (28:5).

The RAFTS syllabus should expand on the SUPT syllabus to include the basic core flying accomplished in the Lead-In Training (LIT) syllabus at Holoman AFB, New Mexico (Figure 4). The LIT syllabus currently uses the T-38B for its training, and it has proven to be an effective aircraft for this lead-in training to fighter/attack aircraft. Although the tactical community has prefered LIT training be accomplished by experienced tactical pilots at a tactical command base, the advent of SUPT and the RAFTS will provide the necessary impetus to include LIT with undergraduate pilot training. The U.S. Navy has combined their lead-in fighter training with the undergraduate program for many years under a dual-track training program similar to SUPT. The Royal Air Force and German Air Force also use a similar SUPT syllabus for their pilot training programs.

The SUPT syllabus is designed to screen students at the end of the primary phase of pilot training and to select only those volunteer students who meet the selection criteria for the FAR track. Because about 40% of the primary graduates will go to the FAR track and 60% to the TTB track, there will be fewer students advancing to a RAFTS syllabus. The planned maximum pilot production for the 1990s is 2,200 pilots which will result in approximately 900 students a year advancing to the RAFTS syllabus. The decreased number of students will be trained at only two ATC bases, Laughlin AFB and Williams AFB. The tactical experienced instructor pilots could be concentrated at these bases to facilitate the core training now accomplished at LIT. The transition, instrument, formation maneuvers, and basic fighter maneuver sorties from the LIT syllabus could be combined into the SUPT syllabus to form the RAFTS syllabus. Depending on the actual design capabilities of the T-38 replacement, additional hours could be included in the syllabus for advanced fighter maneuvers, aerial combat maneuvers, defensive maneuvers, and surface attack. Inclusion of these maneuvers would complete the blending of the Lead-In Training with undergraduate pilot training.

The obvious advantages in such a combination of syllabi could only be realized with the right kind of training aircraft in a total training system. The U.S. Navy's new T-45, the Hawk of the Royal Air Force, and the Alpha Jet of the German Air Force are all 1980 versions of this concept. The T-38 replacement for the 21st century should be able to accompish all the training requirements unique to a combined syllabi concept and to integrate the technological advances into a Recconnaissance Attack Fighter Training System (Figure 5).



UPT & SUPT COMPARISON WITH RAFTS

Figure 4

UPT SYLLABUS	Dual	Solo	IFS
Contact	20/24.0	11/13.2	
Instrument	4/ 5.6		26/33.8
Formation	21/27.1	11/14.1	
Navigation	11/14.4	2/2.6	
TOTAL	56/71.1 + 24/29.9		26/33.8
	80/101		

SUPT SYLLABUS	Dual	Solo	IFS
Contact	22/26.4	10/12.0	
Instrument	4/5.2		27/35.1
Formation	24/28.8	10/12.0	
Navigation	15/20.0	2/2.6	
TOTAL	65/80.4 + 22/26.6		27/35.1
	87/107		

RAFTS SYLLABUS	Dual	Solo	IFS
Contact	22/26.4	10/12.0	
Instrument	4/5.2		27/35.1
Formation	24/28.8	10/12.0	
Navigation	15/20.0	2/2.6	
Lead-In Training	26/25.6	____	
TOTAL	91/106.0 + 22/26.6		27/35.1
	113/132.6		

SYLLABI FLYING HOUR SUMMARY (sorties/hours)

Figure 5

Chapter Eight

CONCLUSION: A CONCEPTUAL DESIGN FOR THE 21st CENTURY

The T-38 replacement must be designed to meet future pilot training requirements. The key requirements include performance and systems which will bridge the gap between the T-46A and the ATF. The aircraft must be part of a system which teaches basic piloting skills and is also capable of basic fighter maneuvering to prepare students for advanced fighter aircraft. The aircraft will be the focal point of an integrated training system with ground, simulator, and aircraft training linked together for the maximum transfer of training between the RAFTS and the ATF.

The T-38 replacement must have a tandem ejection seat design. Reclining seats will allow the crewmembers to maintain higher sustained "G" forces than the conventional straight back ejection design. The higher seating of the instructor pilot in the rear seat should provide for maximum visibility from the rear cockpit. The instructor and student cockpits will be characterized by full digital CRT displays with the conventional round dials as a back-up. An advanced wide angle HUD will be fully integrated into the cockpit systems for the student, and the instructor will have a HUD repeater capability on the rear cockpit CRT.

Flight controls will also be digitally controlled by a fly-by-wire system. This system will enable the aircraft to take advantage of modern wing designs such as the forward swept or the cranked arrow design (14:1-3). The modern wing designs will, in turn, provide increased lift and decreased drag resulting in more in-flight maneuverability and short takeoff and landing capabilities.

The technology of composite materials and miniaturized components will keep the weight of the aircraft down and allow for a high thrust-to-weight ratio when combined with modern fan jet engine technology. The aircraft will have at least a 1:1 thrust-to-weight ratio and be capable of supersonic dash in the 1.5-2.0 mach range (Figure 3). The added thrust will also provide enhanced maneuverability in the sub-sonic regime

Any conceptual design can be altered dramatically by technological improvements or new training requirements. This design, susceptable as it is to change, must have a baseline from which to start. The study addresses the major factors affecting the future pilot training environment and combines them with the technology most important in developing a conceptual training aircraft design. Certainly, there is a long list of new and proposed technology that could possibly be used in the T-38 replacement. However, this study orients the aircraft design toward the undergraduate pilot training requirement of the RAFTS.

The T-38 replacement will not be a gold-plated aircraft for Air Training Command. It will use the technology available now and in the 1990s to meet undergraduate pilot training requirements. The acquisition of the T-38 replacement will have the distinct advantage of using technology which has already completed research and development. The longevity of the T-38 as a viable training aircraft can be directly attributed to its design, which used the technology available in the late 1950s. The conceptual design of the T-38 replacement must proceed in the same way. It must use the most advanced systems and aircraft designs available, if it is to take the Air Force pilot training program into the 21st century.

The Secretary of the Air Force, Verne Orr, said at the recent roll out ceremony of the first new T-46A, "We must have the best trainer we can find. The T-46 fills that role.. It should be an outstanding trainer in years to come." (11:29) In the years to come, a future Secretary of the Air Force will say similar words at the roll out ceremony of the first T XX, the replacement for the T-38 in the Reconniassance Attack Fighter Training System.

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